PRELIMINARY
OPERATOR'S MANUAL

MODEL 552A
DUAL CHANNEL
PROGRAMMABLE FILTER

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CABLE WAVETEK

Dear Wavetek Customer,

Thank you for ordering a Model 552A. The enclosed operator's manual is a preliminary edition. The final version will contain additional sections covering theory of operation, calibration, trouble shooting and schematics. A copy of this new manual will automatically be sent to you when available.

If you have any questions in the interim regarding the operation of the instrument, kindly direct them to either our Customer Service Department or myself. We will be happy to respond.

Sincerely,

James Riley
Product Manager,
Filters & Synthesizers
Business Unit

CONTENTS

SECTION 1 GENERAL DESCRIPTION

1.1 INTRODUCTION 1-1
1.2 DEFINITIONS 1-1
1.3 SPECIFICATIONS 1-1
1.3.1 Cutoff Frequency (F_c) 1-1
1.3.2 Full Scale Sensitivity 1-1
1.3.3 Post-Filter Gain 1-1
1.3.4 Filter Characteristics 1-1
1.3.5 Input Characteristics 1-2
1.3.6 Output Characteristics 1-2
1.3.7 General 1-2
1.3.8 Options 1-2

SECTION 2 INITIAL PREPARATION

2.1 INSPECTION 2-1
2.2 MECHANICAL INSTALLATION 2-1
2.3 ELECTRICAL INSTALLATION 2-1
2.2.1 Power Connection 2-1
2.2.2 Signal Connection 2-1
2.2.3 GPIB (IEEE-488) Interface 2-1
2.2.4 RS-232-C Interface 2-3
2.4 INITIAL CHECKOUT PROCEDURE 2-4

SECTION 3 OPERATION

3.1 INTRODUCTION 3-1
3.2 CONTROLS AND CONNECTORS 3-1
3.3 TYPICAL OPERATING PROCEDURES 3-1
3.3.1 Mode Selection 3-1
3.3.2 Setting Full Scale Sensitivity 3-2
3.3.3 Setting Cutoff Frequency 3-2
3.3.4 Increment/Decrement Keys 3-2

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SAFETY

This instrument is wired for earth grounding via the facility power wiring. Do not bypass earth grounding with two wire extension cords, plug adapters, etc.

BEFORE PLUGGING IN the instrument, comply with installation instructions.

MAINTENANCE may require power on with the instrument covers removed. This should be done only by qualified personnel aware of the electrical hazards.

The instrument power receptacle is connected to the instrument safety earth terminal with a green/yellow wire. Do not alter this connection. (Reference: ⏚ or ⚠ stamped inside the rear panel near the safety earth terminal.)

WARNING notes call attention to possible injury or death hazards in subsequent operations.

CAUTION notes call attention to possible equipment damage in subsequent operations.

Model 552, Dual Channel Programmable Filter

SECTION 1
GENERAL DESCRIPTION

1.1 INTRODUCTION

Model 552A is a programmable, two-channel lowpass filter offering exceptional sensitivity and superior performance in the passband and stopband.

The instrument employs a 5th-order elliptic filter with design values of 0.5 dB ripple in the passband and greater than 72 dB stopband attenuation. The transition from passband to stopband has a rolloff rate greater than 50 dB per octave. The stopband is at 2.56 times the cutoff frequency.

The cutoff frequency may be programmed from 10 Hz to 50 kHz with 2-digit resolution. Full scale input sensitivity from 1 mVrms (− 60dBV) to 10 Vrms (+ 20 dBV) is selectable in steps of 5 dB. Another 10 dB of gain may optionally be applied at the filter output.

This instrument is extremely valuable in signal processing applications for band-limiting prior to sampling to prevent aliasing. In addition to the filtering capability, it provides programmable low noise amplification for applications involving low-level signals and over load indicators to ensure operation in their linear range.

The instrument is controlled locally from the front panel using an elastomeric keypad and dual liquid crystal displays showing all filter and gain parameters. The unit is controlled remotely via two standard interfaces: IEEE 488 and RS-232-C. Programmed parameters are shown on the front panel displays.

1.2 DEFINITIONS

The cutoff frequency, F_c, is the frequency at which the response of the filter drops below the specified passband ripple, A_{max}. The conventional − 3 dB frequency criterion has no significance in an elliptic filter.

Frequency F_s is the lowest frequency for which the stopband attenuation value, A_{min}, applies.

1.3 SPECIFICATIONS

1.3.1 Cutoff Frequency (F_c)

Range
10 Hz to 50 kHz.

Control
Local: Elastomeric digital keypad and dual LCD displays.
Remote (Standard): IEEE 488 and RS-232-C.

Resolution

Multiplier	Frequency (Hz)	Resolution (Hz)
x10	10 — 990	10
x100	100 — 9.9K	100
x1K	1.0K — 50K	1K

Accuracy
− 0.25 dB ± 0.1 dB at F_c.

Stability
± 200 ppm/°C.

1.3.2 Full Scale Sensitivity

Range
− 60 dBV (1 mV) to + 20 dBV (10 V) rms full scale.

Resolution
5 dB steps.

Accuracy
± 0.2 dB.

1.3.3 Post-Filter Gain

Range
0 or + 10 dB.

Accuracy
± 0.2 dB.

1.3.4 Filter Characteristics

Type
5-pole, 4-zero elliptic.

Rolloff
>53 dB/octave.

Frequency Response

± 0.25 dB dc to F_c
− 20 dB at 1.37 F_c (nominal)
− 40 dB at 1.83 F_c (nominal)
− 60 dB at 2.34 F_c (nominal)
− 72 dB above F_s = 2.56 F_c.

Amplitude Match (between channels)
± 0.1 dB, dc to 0.8 F_c, ± 0.2 dB, 0.8 F_c to F_c.

Phase Match (Between Channels)
± 1° (± 1/2° typical) for dc to 0.8 F_c.
± 2° (± 1° typical) for 0.8F_c to F_c.

1.3.5 Input Characterictics

Coupling
DC or ac with nominal 0.5 Hz cutoff.
AC coupling forced for full scale sensitivity from − 40 dBV to − 60 dBV.

Impedance
1 MΩ and 50 pF nominal.

Equivalent Input Noise
− 150 dBV/Hz (− 160 dBV/Hz typical) at 1 kHz with − 60 dBV full scale sensitivity setting sensitivity.

1.3.6 Output Characteristics

Impedance
50 Ω nominal.

Full Scale Signal
1 Vrms into R_L > 5 kΩ, no output gain.
3.16 Vrms into R_L > 5 kΩ, + 10 dB output gain.

Noise (1 MHz detector BW)
>70 dB below full scale referred to output at 0 dBV full scale sensitivity.
<10 uV referred to input at − 60dB full scale sensitivity.

Harmonic Components
>72 dB below full scale for 1 kHz input signal.

Spurious Components
>72 dB below full scale (includes line-related spurious) for full scale sensivity from + 20 dBV to − 50 dBV.
>65 dB below full scale, for full scale sensitivity at − 55 dBV or − 60dBV.

Intermodulation Products
>70 dB below full scale for 40 kHz and 50 kHz input frequencies.

DC Offset
< ± 10 mV, adjustable to 0 Vdc.

DC Drift
± 50 mV maximum, + 15° to + 40°C at 0 dB full scale sensitivity setting.

1.3.7 General

Configuration
Bench top, convertable to rack mounting.

Input/Output Connectors
Front Panel BNCs.

Accessories Supplied
Instruction manual, line cord.

Temperature
0°C to + 40°C for operation; − 20°C to + 70°C for storage.

Dimensions
43.2 cm (17 in) wide; 8.9 cm (3.5 in) high; 41.3 cm (16.3 in) deep.

Weight
33 kg (15 lb) net.

Power
100/120/220/240 VAC ± 10%, 50 to 60 Hz, 50 VA.

1.3.8 Options

004: Rack Mounting Kit

SECTION 2
INITIAL PREPARATION

2.1 INSPECTION

After unpacking the instrument, visually inspect all external parts for possible damage to connectors, surface areas, etc. If damage is discovered, file a claim with the carrier who transported the unit. The shipping container and packing materials should be saved in case reshipment is required.

2.2 MECHANICAL INSTALLATION

The Model 552A is designed for bench top operation or standard 19-inch RETMA rack mounting. Ambient temperature within the rack must not exceed +40°C while the instrument is operating. The rear panel switches should be set before installing the filter in the rack.

2.3 ELECTRICAL INSTALLATION

2.3.1 Power Connection

The instrument will operate from any of the following line voltages: 100, 120, 220 or 240 Vac ± 10%, 50 to 60 Hz. Voltage selection is made using the card inside the power cord receptacle on the rear panel. (See figure 2-1.)

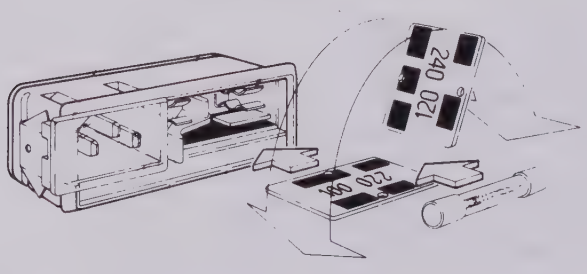


Figure 2-1. Voltage Selection and Fuse Replacement

WARNING

In keeping with standard safety practice, the case of the instrument is grounded through the power cord. If the instrument must be connected to a two wire receptacle, use a parallel ground adapter and connect the short lead to ground.

The line fuse is also contained inside the power cord receptacle. For 100 or 120 Vac operation, the fuse should be a 1/2A SB fuse; for 220 or 240 VAC operation is should be a 1/4A SB fuse.

2.3.2 Signal Connection

Use RG58U 50 Ω coaxial cables when connecting this instrument to associated equipment.

2.3.3 GPIB (IEEE-488) Interface

2.3.3.1 GPIB Connection

The GPIB (IEEE-488) I/O rear panel connection is shown in figure 2-2; pin connections and signal names are given in table 2-1.

Table 2-1. GPIB Data In/Out

Pin	Signal	
1	DIO1	True When Low
2	DIO2	
3	DIO3	
4	DIO4	
5	EOI	
6	DAV	
7	NRFD	True When High
8	NDAC	
9	IFC	True When Low
10	SRQ	
11	ATN	
12	Chassis Ground	
13	DIO5	True When Low
14	DIO6	
15	DIO7	
16	DIO8	
17	REN	
18		Signal Gnd
19		
20		
21		
22		
23		
24		

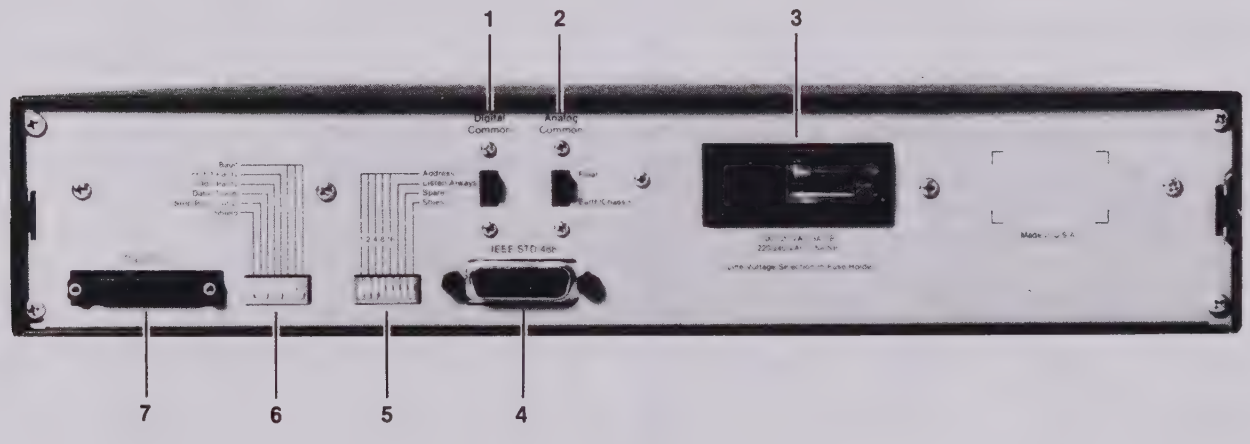
The GPIB panel connector is equivalent to an Amphenol 57-10240 and connectes to a standard GPIB bus cable connector (available from Wavetek in 1 and 2 meter lengths).

2.3.3.2 GPIB Address

Each instrument on the General Purpose Interface Bus (GPIB), must have its GPIB bus address appropriately set. The GPIB address may be selected by the rear panel switch, item 5, shown in figure 2-2. The five address switch sections are labeled on the panel with the binary weight of each switch. The bit weight is ON in the up position of the switch and OFF in the down (OPEN) position.

The LISTEN ALWAYS switch activates this mode in the up position and causes normal addressed operation in the down (OPEN) position.

The SHIELD switch connects the bus cable shield pin to signal ground in the up postion.



Loc	Function
1	Digital Common Float/Ground Switch
2	Analog Common Float/Ground Switch
3	AC Power Receptacle — For IEC power cord; includes fuseholder and line voltage selector
4	GPIB (IEEE 488) Connector
5	GPIB (IEEE 488) Configuration Switch
6	RS-232-C Configuration Switch
7	RS-232k-C Connector — Female DB-25S style

Figure 2-2 Rear Panel Controls and Connectors

Table 2-2. GPIB Address Codes

Device	ASCII		Switch Position					Hexa-decimal	
	Listen	Talk	1	2	3	4	5	Listen	Talk
0	(space)	@	0	0	0	0	0	20	40
1	!	A	1	0	0	0	0	21	41
2	"	B	0	1	0	0	0	22	42
3	#	C	1	1	0	0	0	23	43
4	$	D	0	0	1	0	0	24	44
5	%	E	1	0	1	0	0	25	45
6	&	F	0	1	1	0	0	26	46
7	'	G	1	1	0	0	0	27	47
8	(	H	0	0	0	1	0	28	48
9	)	I	1	0	0	1	0	29	49
10	*	J	0	1	0	1	0	2A	4A
11	+	K	1	1	0	1	0	2B	4B
12	,	L	0	0	1	1	0	2C	4C
13	—	M	1	0	1	1	0	2D	4D
14	.	N	0	1	1	1	0	2E	4E
15	/	O	1	1	1	1	0	2F	4F
16	0	P	0	0	0	0	1	30	50
17	1	Q	1	0	0	0	1	31	51
18	2	R	0	1	0	0	1	32	52
19	3	S	1	1	0	0	1	33	53
20	4	T	0	0	1	0	1	34	54
21	5	U	1	0	1	0	1	35	55
22	6	V	0	1	1	0	1	36	56
23	7	W	1	1	1	0	1	37	57
24	8	X	0	0	0	1	1	38	58
25	9	Y	1	0	0	1	1	39	59
26	:	Z	0	1	0	1	1	3A	5A
27	;	[	1	1	0	1	1	3B	5B
28	<	\	0	0	1	1	1	3C	5C
29	=	]	1	0	1	1	1	3D	5D
30	>		0	1	1	1	1	3E	5E

NOTE
Address 31 is not allowed.

2.3.4 RS-232-C Interface

2.3.4.1 RS-232-C Connection

A standard DB-25F (female) connector on the rear panel of the instrument provides connections for RS-232-C signals. The mating connector should be equivalent to a DB-25P (male) connector, commonly available from computer or electronic accessory suppliers.

The wiring of the connector conforms to that for DCE (Data Communication Equipment). The signals present are listed in Table 2-3

Table 2-3. RS-232-C Connector Pins

Pin	Signal	In/Out	Description
1	PG	—	Protective Ground
2	TxD	IN	Transmitted Data (Note 1)
3	RxD	OUT	Receive Data (Note 1)
4	RTS	IN	Request to Send
5	CTS	OUT	Clear to Send
6	DSR	OUT	Data Set Ready
7	GND	—	Signal Ground
8	CD	IN	Carrier Detect (Note 2)
20	DTR	IN	Data Terminal Ready

1. The TxD and RxD line nomenclature is with respect to the controller, not the 552A.
2. Line CD is connected to a line receiver but has no interface function.
3. Pin numbers not shown in the above chart have no internal connection.

2.3.4.2 RS-232-C Parameters

The RS-232-C Parameter switch on the rear panel shown in figure 2-2, is used to set parity, stop bit and baud rate for the RS-232-C port. Table 2-4 shows the function of each switch.

Table 2-4. RS-232-C Parameter Switches

Switch	Function	Position	Effect
1	Shield	UP	Prot. GND tied to Sig. GND
		DN	Prot. GND floating
2	Stop Bits	UP	2 Stop Bits
		DN	1 Stop Bit
3	Data Bits	UP	8 Data Bits
		DN	7 Data Bits
4	Parity	UP	Odd Parity
		DN	Even Parity
5	Parity Inh	UP	Parity Inhibited
		DN	Parity Enabled
6,7,8	Baud Rate	UP	= Logic 1
		DN	= Logic 0

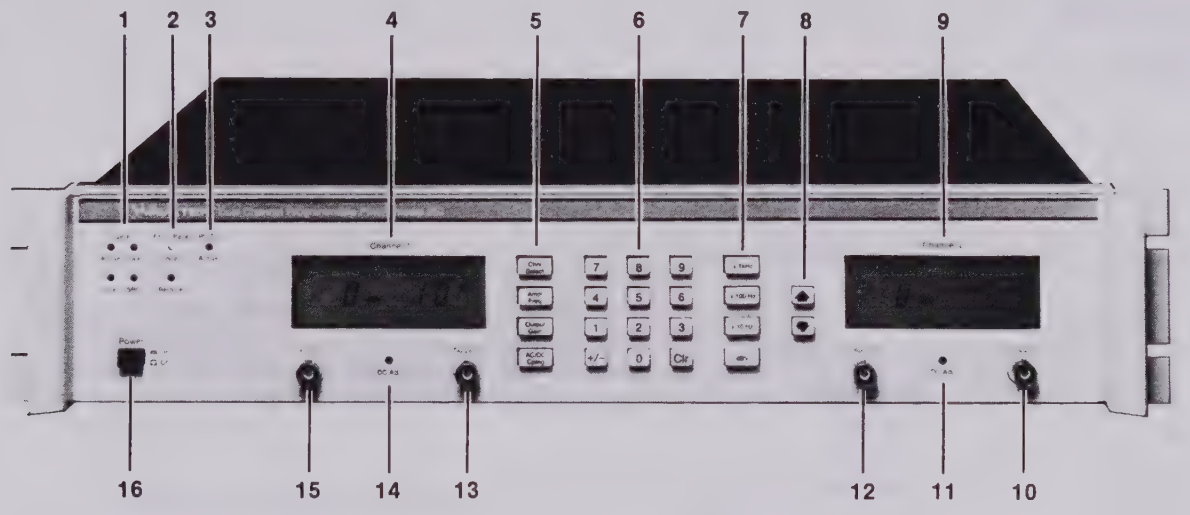
Switch 6 7 8	Baud Rate
0 0 0	110
0 0 1	150
0 1 0	300
0 1 1	600
1 0 0	1200
1 0 1	2400
1 1 0	4800
1 1 1	9600

Table 2.6 Checkout Procedure

Step	Control	Operation	Observation
1	**Power**	**On**	All LED's flash, then **Local** LED stays on. LCD's indicate 0 dBV, DC and 10 kHz, on both channels. Cursor (underline) under CUTOFF FREQ, on **Channel 1** only
2	**Chan Select**	Press once	Cursor under CUTOFF FREQ on **Channel 2**
3	**Chan Select**	Press once	Cursor under CUTOFF FREQ on both channels
4	**1**	Press once	Both cursors flash, 1 kHz displayed on both channels
5	**0**	Press once	10 kHz displayed on both channels
6	**X10 Hz**	Press once	Cursors stop flashing, .10 kHz displayed on both channels
7	*(Set Synthesizer to 90 Hz)*		2 V p-p on scope Ch 1. Verify 2 V p-p on scope Ch 2
8	*(Set Synthesizer to 200 Hz)*		Verify about 10 mV p-p on scope Ch 2
9	*(Move **Input 1** and **Output 1** Cables to **Input 2** and **Output 2**. Repeat steps 7 and 8)*		
10	**X100 Hz**	Press once	1.0 kHz displayed on both channels
11	*(Set Synthesizer to 900 Hz)*		Verify 2 V p-p on scope Ch 2
12	*(Set Synthesizer to 2 kHz)*		Verify about 10 mV p-p on scope Ch 2
13	*(Move cables to **Channel 1** and repeat steps 10 and 11)*		
14	**X1kHz**	Press once	10 kHz displayed on both channels
15	*(Set Synthesizer to 9 kHz)*		Verify 2 V p-p on scope Ch 2
16	*(Set Synthesizer to 20 kHz)*		Verify about 10 mV p-p on scope Ch 2
17	*(Move cables to **Channel 2** and repeat steps 14 and 15)*		
18	**Ampl Freq**	Press once	Cursors under FULL SCALE on both channels
19	*(Set Synthesizer to 1 kHz*		Verify 2 V p-p on scope Ch 2
20	⬇	Press once	FULL SCALE reading shows −5 dBV on both channels

Table 2.6 Checkout Procedure (Continued)

Step	Control	Operation	Observation
21	*(Set Attenuator to 5 dB)*		Verify 2 V p-p on scope Ch 2
22	*(Move cables to **Channel 1**)*		Verify 2V p-p on scope Ch 2
23	**2**	Press once	– 2 dBV on both displays, both cursors flashing
24	**0**	Press once	– 20 dBV on both displays
25	**dBV**	Press once	– 20 dBV on both displays, cursors stop flashing
26	*(Set Attenuator to 20 dB)*		Verify 2 V p-p on scope Ch 2
27	*(Move cables to **Channel 2**)*		Verify 2 Vp-p on scope Ch 2
28	+/–	Press once	+ 20 dBV on both displays, cursors flashing
29	**dBV**	Press once	+ 20 dBV on both displays, cursors stop flashing
30	*(Set Attenuator to 0 dB)*		Verify about 0.2 V p-p on scope Ch 2
31	*(Move cables to **Channel 1**)*		Verify about 0.2 V p-p on scope Ch 2
32	**Output Gain**	Press once	Verify + 10 dB Output Gain message on display on both channels. Verify about 0.72 V p-p on scope Ch 2
33	*(Move cables to **Channel 2**)*		Verify about 0.72 V p-p on scope Ch 2



Controls and Indicators

Loc	Function
1	**GPIB** Status Indicators — Displays the status of the GPIB interface.
2	**Front Panel** Status Indicators — Front panel keyboard is active in **Local** and disabled in **Remote**.
3	**RS 232** Status Indicator — Displays status of RS-232-C remote interface.
4	**Channel 1** LCD Display — Displays cutoff frequency, sensitivity, input coupling and output gain for channel 1.
5	Mode Select Keypad — Selects parameter to be loaded via the front panel.
6	Numeric Keypad — Used for front panel entry of cutoff frequency and sensitivity data.
7	Units Keypad — Used for entering the frequency multiplier or dBV terminator for keypad data entries.

Loc	Function
8	Increment, Decrement Keypad — Used for incrementing or decrementing either cutoff frequency or sensitivity.
9	**Channel 2** LCD Display — Displays cutoff frequency, sensitivity, input coupling and output gain for channel 2.
10	**Output 2** — Channel 2 output BNC.
11	**DC Adjust** — DC Level adjustment for channel 2.
12	**Input 2** — Channel 2 input BNC.
13	**Output** — Channel 1 output BNC.
14	**DC Adjust** — DC level adjustment for channel 1.
15	**Input 1** Channel 1 input BNC.
16	**Power** Switch — Controls ac line power to instrument.

Figure 3-1. Front Panel Controls and Indicators

SECTION 3
OPERATION

3.1 INTRODUCTION

This section describes how to operate the Model 552A. The controls and front panel indicators are described followed by typical operating procedures and response characteristics. Finally, the GPIB and RS-232-C interfaces are described.

3.2 CONTROLS AND INDICATORS

The front panel controls and displays are described in figure 3-1. The rear panel features are described in figure 2-2. The LCD display is separately described in figure 3-3.

3.3 TYPICAL OPERATING PROCEDURES

The dual LCD's (liquid crystal displays) on the front panel reflect the current operating status of the filters, whether controlled from the front panel (local) or through one of the remote interfaces.

There are two general rules regarding the operation of the front panel keypad and LCD displays:

- The cursors (solid lines underneath the FULL SCALE and CUTOFF FREQ legends) when displayed, show where keyboard data will be directed. If the cursor is flashing, data entry is in process and the display reflects a partial or unterminated value.
- The final value displayed after data entry (cursor not flashing) will always be set at the actual operating value of the filter. If an illegal or out of range value was entered, the nearest valid value is chosen.

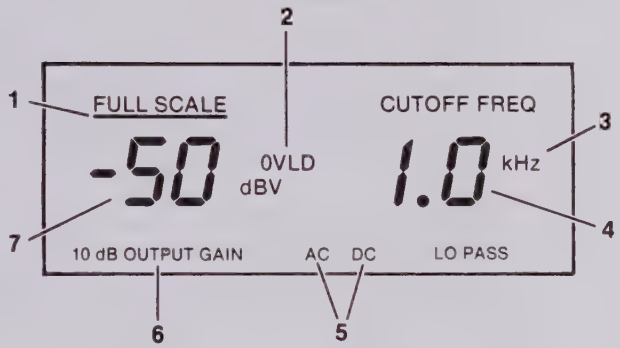
3.3.1 Mode Selection

Channel Selection

The **Chnl Select** key causes the cursor to shift among three modes: **Channel 1** only, **Channel 2** only, or both channels. Each time this key is pressed, the cursor will shift and display either one or both LCD's.

Amplitude/Frequency Select

The **Ampl/Freq** key toggles the cursor position within the selected channel(s) to either FULL SCALE Sensitivity (amplitude) or CUTOFF FREQuency. Each time this key is pressed, the cursor shifts to the alternate position.



Loc	Function
1	Cursor — Solid line under the FULL SCALE legend indicates Full Scale program mode. Solid line under the CUTOFF FREQ legend indicates the Cutoff Frequency program mode.
2	OVLD Indicator — Indicates an overload condition when displayed.
3	Cutoff Frequency Multiplier — Shows either Hz or kHz multiplier for cutoff frequency digits.
4	Cutoff Frequency Digits — Two digits with decimal point showing the cutoff frequency setting.
5	Input Coupling Mode — Displays either AC or DC input coupling status.
6	Output Gain Status — Displays either nothing (0 dB) or 10 dB Output Gain status.
7	Full Scale Sensitivity Digits — Two digits plus polarity showing the full scale sensitivity setting.

Figure 3-2. LCD Display

3.4 Remote Operation

3.4.1 Introduction

The instrument comes equipped with two standard remote interfaces: GPIB (General Purpose Interface Bus) and the RS-232-C Serial Interface.

Each interface has its own special hardware configuration and interface control commands, but the programming command language for both is essentially the same.

Some of the program commands for one interface relate to aspects of the other interface, but are included for the sake of uniformity and for applications where both interfaces may be used alternately. For example, the status of the RS-232-C UART is readable over the GPIB interface.

3.4.2 Remote Interface Priority

The RS-232-C interface has a higher priority than the GPIB interface. Both interfaces have priority over front panel local control, but the front panel can be active while either interface is active.

Only one of the two interfaces can be active at any given time. If both interfaces are used alternately, the instrument can respond correctly. Programmed values and instrument status do not change when exiting and entering the remote modes.

As described more fully in section 3.6, either a low-to-high transition on the RS-232-C DTR line or the receipt of a '!' on the RS-232-C port while the GPIB mode is active will abort the GPIB mode and reset any active LISTEN or TALK state. Any command sequence in progress will be lost. When RS-232-C mode is exited, the GPIB mode will have to be re-established.

CAUTION

If the state of the DTR line is changed during any GPIB or RS-232-C data transfer, unpredictable results may occur.

3.5 GPIB Interface

The GPIB interface is an implementation of the IEEE specification 488-1978. It supports the following interface functions which are described in detail in the

specification. Relevant aspects of these functions are described in the following paragraphs:

SH1	Complete Source Handshake
AH1	Complete Acceptor Handshake
T6	Basic Talker
TE0	No Extended Listener
L3	Basic Listener
LE0	No Extended Listener
SR1	Complete Service Request
RL1	Remote/Local and Local Lockout
DC1	Device Clear and Selective Device Clear
DT1	Complete Device Trigger
E2	Tri-State Drivers

Instruments on the bus may have "talk" and "listen" capabilities. The talk capability allows a device to send data (such as error message readings) out over the bus. The listen capability allows a device to receive data (such as device programming information) from the bus.

The GPIB consists of 16 negative true signal lines as shown in figure 3-4. These 16 lines include 8 bi-directional data lines, 3 handshake lines and 5 control lines. All devices on the bus interface to these lines with passive pull up and active pull down. Thus, any devices may "assert" a line by pulling it down to the logic low, or "true" state. If no device is asserting the line, it is pulled up to the logic high, or "false" state. (Only the controller is allowed to assert certain lines.)

As shown in figure 3-4, devices connected to the bus may be a LISTENER (only), TALKER (only), LISTENER/TALKER or CONTROLLER. More than one controller may be connected to the bus, but only one controller may be hard wired as SYSTEM CONTROLLER and only one controller at a time may assume the role of ACTIVE CONTROLLER.

3.5.1 Bus Line Definitions

The 16 negative-true GPIB signal lines are:

DIO1 - DIO8	Data In/Out Lines
ATN	Attention
REN	Remote Enable
DAV	Data Available
NRFD	Not Ready for Data
NDAC	Not Data Accepted
EOI	End Or Identify
SRQ	Service Request
IFC	Interface Clear

The functions of the GPIB signal lines are:

D101-D108	These eight lines (Data In/Out) are used to send commands from the controller and to transfer data back and forth between instruments and the controller.
ATN	The Attention line is operated only by D108 is data (ATN false) or a command (ATN true). Whenever ATN is set true, no activity is allowed on the bus except for the controller originated messages.
REN	The Remote Enable line controls whether devices on the GPIB are in local or remote modes. The Model 552A enters the remote state when it receives its listen address and REN is enabled. The Model 552A than stays in the remote mode until the REN line is put in the local state, a Go To Local (GTL) command is received or the RS-232-C bus takes control,
DAV NRFD NDAC	These are the "handshake" lines (Data Valid, Not Ready For Data and Not Data Accepted), which regulate the transmission of information over the lines D101-D108. For each command or data byte transferred, a complete handshake is designed to hold up the bus until the slowest device has accepted the information.

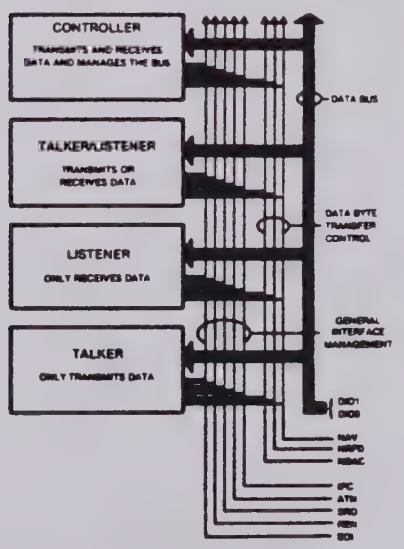


Figure 3-4. GPIB Structure

EOI	When ATN is false, EOI (End Or Identify) indicates that the data on lines D101-D108 is the last byte of a data message. When the Model 552A received a data byte with EOI true, it automatically supplies a terminator character following the data byte. When the Model 552A transmits the last byte of a message (which is always a terminator character) it also sets EOI true.
SRQ	The Service Request line is used by the Model 552A and other devices on the bus to signal the controller that they request attention. Since the SRQ line is common to all devices, additional tests must be made to determine which devices are signaling. The controller performs a Serial Poll to accomplish this.
IFC	The Interface Clear line is asserted by the system controller to reset the interface logic in all devices connected to the bus to a known initial state.

3.5.2 Handshake Sequence

The three handshake lines, Data Valid (DAV), Not Ready for Data (NRFD) and Not Data Accepted (NDAC) are used in a typical data exchange as described in the text paragraph.

All devices currently designated as active listeners would indicate (via the NRFD line) when they are ready for data. A device not ready would pull this line low (ground), while a device that is ready would let the line float high. Since a low overrides a passive high, this line will stay low until all active listeners are ready for data. When the talker senses this, it places the next data byte on the data lines and then pulls DAV low. This tells the listeners that the information on the data lines is valid and that they may read it. Each listener (at its own speed) then takes the data and lets the NDAC line go high. Again, only when all listeners have let NDAC go high will the talker sense that all listeners have read the data. It can then remove DAV (let is go high) and start the entire sequence over again for the next byte of data.

3.5.3 Commands

Commands are sent over lines D101-D108 with ATN true They are divided into five classes:

1. Listen Address

2. Talk Address

3. Secondary Addresses

4. Universal Commands

   DCL Device Clear
   SPE Serial Poll Enable
   SPD Serial Poll Disable
   LLO Local Lockout

5. Addressed Commands

   GTL Go To Local
   SDC Selective Device Clear
   GET Group Execute Trigger

3.5.3.1 Listen Address

Listen addresses are used to command a device to read any data bytes transmitted over lines D101-D108. There are 31 different available addresses (hexadecimal codes 20 through 3E). The unlisten address (hexadecimal 3F) is used to command all devices to not read data bytes. See table 2-2. The Model 552A listen address is selected by rear panel switches. See Figure 2-2.

3.5.3.2 Listen Always Mode

For applications which do not require selective addressing of listeners, a Listen Always (Listen Only) mode is available. When this mode is selected, whenever the REN line goes true, the Model 552A is automatically addresed as a listener and is ready to receive bus messages.

The rear panel Listen Always switch is described in section 2.3.3.2.

3.5.3.3 Talk Address

Talk addresses are used to command a device to transmit data over lines D101-D108. There are 31 different available addresses (hexadecimal codes 40 through 5E). The untalk address (hexadecimal 5F) is used to command all devices to cease talking. The lower 5 bits of the Model 552A talk address are selected by the same

switches used to select the listen address. Thus, if the listen address is hexadecimal 21, the talk address is hexadecimal 41.

3.5.3.4 Secondary Address

Secondary addresses are used following a talk or listen address to provide the ability to address more than the 31 devices provided for by simple talk or listen addresses. Secondary addresses are ignored by the Model 552A.

3.5.3.5 Universal Commands

Universal commands are used to command a device to perform designated actions. Universal commands are recognized at all times. Universal commands performed by the Model 552A are:

1. Device Clear (DCL) - Resets the instrument to the power on default settings. DCL affects all devices on the bus.

2. Serial Poll Enable (SPE) - Causes the instrument to engage in a serial poll by responding with the serial poll status byte when addressed as a talker. Data line D107 will be on, if service is being requested on the SRQ line. When the status byte is read, it is reset to all zeros, and the SRQ line is released (of course, it may still be held down by other devices). The status byte is also available by reading the Model 552A talk mode T1 message. When this message is read, the status byte is reset and the SRQ released as for the serial poll.

3. Serial Poll Disable (SPD) - Discontinues serial poll. Returns instrument to normal talk modes.

4. Local Lockout (LLO) - Causes the instrument to enter a state where the front panel keys are inoperative. In this state the instrument will only accept parameter changes through the remote interfaces. To enable front panel parameter changes, the GPIB controller can send the GTL (Go To Local) command.

3.5.3.6 Addressed Commands

Addressed commands are used to command a device to perform designated actions. Addressed commands are recognized only when the instrument is addressed as a listener. Addressed commands performed by the Model 552A are:

1. Go To Local (GTL) - Commands the Model 552A to enable front panel control.

2. Selective Device Clear (SDC) - Resets the Model 552A to its power on default conditions. SDC affects only the selected unit.

3. Group Execute Trigger (GET) - Upon receipt of the GET, the scratchpad programmed settings are error checked. If no error is detected, the control information is transferred to the operational section of the instrument. This has the same effect as the execute command, I (see section 3.5.6).

3.5.4 Characters

There are four types of characters that can be sent over the GPIB bus:

Alphabetic Characters: The characters A, C, D, F, H, I, L, M, O, S, and T select filter or control parameter commands; upper and lower case are treated identically. Any other alphabetic characters are ignored except 'E' (see below).

Number Characters: The numbers '0' through '9', 'E' (exponent), '-' (negative, and the decimal point determine the parameter value or control code.

Terminator Characters: The CR (carriage return) or LF (line feed) characters terminate the end of a character string. Either one or both of these may be present at the end of incoming strings. When transmitting, the Model 552A always sends both (CR + LF) as a terminator.

Non-programming Characters: Any character not described above is ignored and may be interspersed freely after any programming character.

3.5.5 Types of Commands

There are two types of commands: filter parameter commands and control parameter commands.

Filter parameters deal exclusively with the values of the settings for the filter or gain stages, such as cutoff frequency and input sensitivity. All of these commands are buffered in a scratchpad memory area as they are received, and are not directed to the operational sections of the instrument until the execute (I) command is received.

Control parameters deal with the programming mode and function of the interface but do not directly affect filter settings such as cutoff frequency. These com-

mands are not buffered in a scratchpad memory and do not need an execute (I) command. Their effect is immediate as soon as they are received and processed.

3.5.6 The Execute Command (I)

None of the filter parameters in the scratchpad is executed until the execute command (I) is received. After the 'I' command, the contents of the scratchpad are examined and corrected for class 2 errors (see section 3.5.7.2). The validated contents of the scratchpad memory are then transfered to the operational control registers.

An execute (I) may be sent as the last character in the parameter string if the new parameter is to be executed immediately.

It is also possible to send multiple commands in the same string. For example, to send cutoff frequency and input sensitivity in the same string simultaneously, send the parameter string: 'F10E3S-10I'. In this case, the cutoff frequency of 10 kHz and input sensitivity of -10 dBV are executed simultaneously when the command line is processed.

3.5.7 Error Checking

After the Model 552A receives the command string terminator, the command string is processed to remove any non-programming characters (see section 3.5.4). Each parameter value is then truncated to an integer value and then tested to determine if it is a legal value for that parameter.

For frequency values with more than two digits of resolution, only the first two digits are retained. No error will be generated in this case.

3.5.7.1 Class 1 Errors - Out of Range

Class 1 errors are errors caused by programming values outside the valid limits of the selected parameter. For example, programming a cutoff frequency of 100000 Hz will cause a Class 1 error for frequency (since 50 kHz is the largest valid setting).

When this occurs, the instrument disregards this new value and retains the value previously programmed in scratchpad memory. The error is recorded in the error string and may be examined on request (Talk Mode T0 in table 3-5).

Table 3-4. Class 1 Error Guidelines .

Parameter	Legal Truncated Integer Value
Frequency (F)	10 to 50000
Input Sensitivity (S)	-60 to +20
Output Gain (O)	0 to 10
Channel Select (C)	1 to 3
Talk Mode (T)	0 to 6
Local Mode (L)	0 to 1
Handshake (H)	0 to 3
Interrupt Mask (M)	0 to 255

3.5.7.2 Class 2 Errors - Conflict Between Parameters

Class 2 errors are parameter conflicts or inconsistencies. As the command string is processed, any command which conflicts with another parameter in the scratchpad will cause a class 2 error.

The only class 2 error for this instrument occurs when DC coupling is selected for full scale input sensitivities from -40 to -60 dBV. If this conflict exists, it is resolved by forcing AC coupling into the scratchpad. The error is recorded in the error list.

3.5.7.3 Class 3 Errors - Parameter Needs Adjustment

After integer truncation and testing for Class 1 errors, the parameters are adjusted, if necessary, to the nearest exact value which the instrument can execute.

In the case of input sensitivity, the adjustment is made from the truncated integer value to the next exact 5 dB step value of lower sensitivity (towards a more positive value). In no case is input sensitivity adjusted to a more sensitive setting (more negative value). For example, programmed values of S-31 and S-34 would be adjusted to S-30, (-30 dBV FS). This avoids overload problems for computed gain values.

The output gain is adjusted from its truncated integer value to the closer value of 0 dB or 10 dB.

Since all other parameters are selected in integer steps and have already been truncated, reduced to two-digit resolution (frequency values), and tested for correct range, no adjustments are required. Hence, only input sensitivity and output gain can generate class 3 errors.

Whenever an adjustment is necessary, a class 3 error is reported in the error string buffer. The scratchpad memory is loaded with the adjusted value.

3.5.8 Programming Parameters

Filter and control parameter commands require an alphabetic letter character usually followed by a number value.

Only one decimal point and one 'E' (exponent) are allowed per number, all others are ignored. Only two exponent digits are allowed. Any number of non-programming characters may be interspersed with the numeric field as they have no effect.

Data entry can be fixed point, floating point, exponential notation or scientific notation. Any sequence which gives the new value is acceptable. In-line math is not supported. (A parameter value of "5-2" is not acceptable for an intended value of "3".)

For example, all of the following sequences cause the cutoff frequency 100 Hz to be programmed:

Program String	Remarks
F 100	Blank spaces are ignored
F0100	Leading zeroes are ignored
F1E2	$1*10^2 = 100$
F.01E4	$.01*10^4 = 100$
F.01E304	Only last two exponent digits accepted
F1000E-1	$1000*10^{-1} = 100$
F1E-2-	Two minus signs cancel
F1E.2	Decimal point in exponent ignored

Since the numeric input format is so general, the instrument must be told when the last numeric value has been entered so it can evaluate the number. This is done by programming either a legal alphabetic character specifying the next parameter field or a terminator. A non-programming character is not sufficient to terminate the numeric field. When this is done, the new value is integer truncated and tested to see if it is within range. If so, it is either executed (control parameters) or entered into the scratchpad memory (filter parameters). If it is not within range an error string is generated and the previous value is retained.

Note: One exception to the above rules for numeric input format is the numeric format of the interrupt mask (M). It must be entered in integer form using no decimal point or exponent.

3.5.9 Talk Mode

The Model 552A is capable of sending several different messages back to the controller reflecting parameters and status of the instrument. The selection of which message is to be sent is accomplished with the Talk Mode command, Tn, where 'n' is a number between 0 and 6. The description of each command mode is given in Table 3-5 below.

In order to elicit a talk message from the instrument, the controller must first send the appropriate Tn command and then address the unit as a talker.

When requesting a talk message in talk modes T0, T1 and T6 (all error reporting messages), the errors are cleared after the message is sent. In the other talk modes, the same message may be read any number of times.

3.5.10 Service Request (SRQ) Interrupts

The instrument is capable of alerting the controller of an error condition by using the service request (SRQ) line.

Several types of errors are detected in the instrument. The user can specify which errors are to cause an SRQ. Each error condition is enabled by sending the appropriate error weight using the interrupt mask command. The format for this command is the letter 'M 'followed by a decimal number representing the sum of the weights in the following chart.

Weight	Description
128	Address Pass Through Error
64	(not used)
32	Buffer Overflow
16	Overload Channel 2
8	Overload Channel 1
4	Class 3 Error
2	Class 2 Error
1	Class 1 Error

If any of the above errors is enabled by including its corresponding weight in the interrupt mask, then when that error condition occurs, an SRQ interrupt is generated.

For example, if the user required an SRQ for a buffer overflow, an overload on channel 2 or a class 1 programming error, the interrupt mask number (sum of weights) would be decimal 49 (32 + 16 + 1). The program string would be: 'M49'.

To disable all SRQ interrupt error sources, send the string: 'M0'.

When an enabled error occurs, the GPIB Bus SRQ line is sent true. Also, in the serial poll byte, the bit corresponding to the error and the rsv bit are both set to one. The bits will remain set until the serial poll byte is read either by addresing the device as a talker when in talk mode T1 or by issuing a Serial Poll Enable (SPE) sequence. Either of these clears all error bits in the serial poll byte and releases the SRQ line on the bus.

As errors are detected, the corresponding bits in the serial poll byte are set. The serial poll byte thus represents the accumulated error history since the last time the byte was read and cleared. Note that all errors are recorded in the serial poll byte, not just those enabled with the 'M' command. However, only those errors which are enabled will cause an SRQ.

If the user wishes to know the error history, the serial poll byte may be read at any time using an SPE sequence or talk mode T1.

NOTE

Programming changes may cause momentary switching transients leading to a false overload indication (interrupt weight 8 or 16). If a transient causes an overload, the error bit in the serial poll byte will be cleared when read by the controller. If the overload is sustained, after the serial poll byte is read and the error bit cleared, the bit will be again set. In this case, however, a second SRQ will not be generated until after the next 'I' command is sent. This avoids a "race" condition where the controller is constantly servicing the SRQ interrupts.

3.5.11 Programming Reference Guide

A summary of all programming commands follows in two tables. The first shows the control parameters and the second shows the filter parameters. These tables are essentially identical to the RS-232-C commands shown in tables 3-9 and 3-10.

Table 3-5. GPIB Control Parameter Programming

Function	ASCII Character	Description
Channel Select	C	The character 'C' followed by a number determines which channel(s) will be affected by subsequent programming parameters according to the folowing table: Code — Function C1 — Channel 1 Only C2 — Channel 2 Only C3 — Both Channel 1 and 2
Execute	I	The character 'I' is causes the sensitivity and coupling parameters in the scratchpad to be checked for conflicts. If no error is found, the rounded scratchpad contents are transferred to the active parameter table and executed. An execute (I) may be sent as the last character in the parameter string if the new parameter is to be executed immediately.
Interrupt Mask	M	The character 'M' followed by number determines which status bits are enabled to cause an interrupt. The number is the ASCII decimal value of the 8-bit mask byte described below: Weight — Description 128 — 1 = Address Pass Through Error 64 — (not used) 32 — 1 = Buffer Overflow 16 — 1 = Overload Channel 2 8 — 1 = Overload Channel 1 4 — 1 = Class 3 Error 2 — 1 = Class 2 Error 1 — 1 = Class 1 Error If any mask byte bit is set to '1', then when the corresponding condition occurs, an interrupt is generated. If more than one condition is required, then the mask byte should contain '1's for each condition. To disable all interrupt sources, send the string: 'M0'.

Talk Mode	T	The character 'T' followed by a number code (0 through 6) determines the kind of message the Model 552A will send when addressed as a talker. All messages are sent in ACSII format with numbers in decimal form. Following each message is a CR + LF. Following the message, the EOI line is asserted. Code Function **T0 Program Error List** A typical error string is: E1F 2DS The error string has the following characteristics: a. All error strings begin with E. b. Most recent error is at the end of the string. c. Errors are separated by a space. d. Class 1 error: The number '1' followed by the program character that caused the error. (Example, 1F) e. Class 2 error: The number '2' followed by 'DS', since DC coupling (D) and Sensitivity (S) are the only two possible conflicting parameters. f. Error strings can be up to 80 characters long. g. After transfer, the error string is cleared. **T1 Serial Poll Byte Response** The serial poll status byte is converted to an ASCII decimal number between '0' and '255'. After the string is sent, the serial poll status byte is cleared to all zeroes and the SRQ line is released (see section 3.5.10). The serial poll status byte has the following format:

Weight	Description
128	1 = Address Pass Through Error
64	1 = Request for Service (rsv)
32	1 = Buffer Overflow
16	1 = Overload Channel 2
8	1 = Overload Channel 1
4	1 = Class 3 Error
2	1 = Class 2 Error
1	1 = Class 1 Error

For example, if the number '13' were received (13 = 8 + 4 + 1), a channel 1 overload, a class 3 error, and a class 1 error occured since the byte was last read.

T2 Most Recent Parameter String

The most recently programmed parameter string is sent.

T3 Entire Active Instrument Setup

All control and operating parameters for both channels are sent. Example: C1 F12000 S-60 O00 A C2 F300 S-00 O10 D M008 H2 T3 L1 C1.

The C field precedes the settings for each indicated channel. The F field expresses the cutoff frequency in Hz, no leading zeroes. The S field shows full scale sensitivity in dBV with sign and two digits. Output gain in dB is indicated by O followed by 00 or 10. AC or DC input coupling is shown by the single letter A or D.

The interrupt mask is a three-digit decimal number following the letter M. Handshake Mode, Talk Mode, and Local (Front Panel) Control Mode are all indicated by the single letters H, T and L, respectively, each followed by a single digit.

The final C channel specification shows which channel(s) is selected for subsequent programming.

Note: This string fully represents the instrument configuation. It can be

stored and later sent exactly as is into the instrument to restore this configuration.

T4 Entire Scratchpad Setup

All filter parameter scratchpad values that will be executed with the next execute (I) command are sent. Same format as T3 except only the C, F, S, O, A and D parameters are included.

T5 Identification

Instrument identification and software revision. Example: WAVETEK MODEL 552A REV C.

T6 RS-232-C UART Status

The UART (Universal Asynchronous Receiver/Transmitter) for the RS-232-C port can report its error status with an ASCII decimal number between '0' and '7' according to the table below:

Weight	Description
4	1 = Framing Error
2	1 = Parity Error
1	1 = Overrun Error

For example, a response of the number '5' would indicate an overrun error and a parity error. Once the status is read, it is cleared to '0'.

This status is typically not meaningful in normal GPIB-only programming, but is provided for cases where both interfaces may be used alternately.

xponent E Designates that the numbers immediately preceding 'E' to be raised by the 10th power of the following number, and optional '+' or '-' sign. Example: F300E-1 = $300*10^{-1}$ = 30 Hz.

Local Control L

The character 'L' followed by a number allows the front panel keys to be enabled or disabled during remote control operation according to the following table:

Code	Function
L0	Front Panel Disabled (LLO)
L1	Front Panel Enabled (GTL)

The power up default condition is L0. The GPIB universal command LLO (Local Lockout) is identical to program command L0, and universal command GTL (Go To Local) is identical to L1.

Handshake H

The character 'H' followed by a number allows alteration of the RS-232-C interface software and hardware handshake protocols described in section 3.6.4 as follows:

Code	RTS/CTS (Hardware)	XON/XOFF (Software)
H0	Off	Off
H1	On	Off
H2	Off	On
H3	On	On

Note: The power up default condition is H0.

This status is typically not meaningful in normal GPIB-only programming, but is provided for cases where both interfaces may be used alternately.

Table 3-6. GPIB Filter Parameter Programming

Function	ASCII Character	Description
Input Coupling	A	The character 'A' selects AC input coupling for the selected channel(s). No number value is required following the 'A'.
	D	The character 'D' selects DC input coupling for the selected channel(s). No number value is required following the 'D'.
Cutoff Frequency	F	The character 'F' followed by a number value programs the filter cutoff frequency in Hz for the selected channel(s). Valid values are 10 Hz to 50,000 Hz.
Output Gain	O	The character 'O' followed by a number value determines the post-filter output gain in dB for the selected channel(s). Valid values are either 0 dB or 10 dB.
Input Sensitivity	S	The character 'S' followed by a number value determines the full scale input sensitivity of the selected channel(s) expressed in dBV, where 0 dBV equals 1 Vrms. Valid values are -60 dBV to +20 dBV, in increments of 5 dB.

3.6 RS-232-C Interface

3.6.1 Initial Preparations

Connect the controller to the Model 552A using an appropriate cable. Section 2.3.4.1 describes the RS-232-C rear panel connector wiring.

The rear panel RS-232-C parameter switches must be set according to the parameters of the controller. In general, the highest available baud rate should be used to minimize message transmission time. The switches are described in 2.3.4.2.

3.6.2 General RS-232-C Information

3.6.2.1 RS-232-C Voltage Levels

Data signal lines (TxD and RxD) use a voltage of +3 to +25 volts to represent a zero (also called space) and a voltage of -3 to -25 volts to represent a one (also called a mark).

Control signal lines (RTS, CTS, etc.) use +3 to +25 volts, or high state, to indicate a true condition, and -3 to -25 volts, or low state, to indicate a false condition.

3.6.2.2 Data Transmission

When no data is being transmitted, the idle state of the data lines will be in the mark state (low). To transmit a byte, the transmitting device first sends a start bit which is a space for one bit time (1/baud rate) to synchronize the receiver. Next, 7 or 8 data bits are sent LSB first, then at least one bit time of the mark state (stop bit) before initiating the transmission of the next byte. The baud rate and the number of stop and data bits is selectable using the rear panel RS-232-C switches.

Some devices use an optional parity bit between the data bits and the stop bit. Parity is the even or odd state of the number of 1's in the data field and is used for data error checking. Some systems require the parity bit to be one when even parity exists and some systems require it to be one when odd parity exists. Selection of parity and the odd/even state is accomplished using the rear panel RS-232-C switches.

3.6.3 Initiating RS-232-C Control

There are two actions which initiate the RS-232-C remote mode:

1. A low-to-high transition on the DTR input line.

or

2. The serial control charcter '!' sent on the RxD line.

When the instrument senses a low-to-high transition on the DTR line or detects a '!' character, it acknowledges by sending DSR high and maintaining it high as long as the RS-232-C mode is active.

There are two ways to leave the RS-232-C interface mode and return to LOCAL mode:

1. A high-to-low transition on the DTR line.

or

2. The serial control character '$' sent on the RxD line.

When DTR is sent high-to-low or a '$' is received, the instrument will leave the RS-232-C mode and send DSR low. The DSR line can be used by the controller as an acknowledgement of successful transition into and out of the RS-232-C mode.

3.6.3.1 RS-232-C Priority over GPIB

The RS-232-C mode has priority over the GPIB mode. Either a low-to-high transition on the DTR line or the receipt of a '!' on the RS-232-C port while the GPIB mode is ACTIVE will abort the GPIB mode and reset any active LISTEN or TALK state. Any command sequence in progress will be lost. When RS-232-C mode is exited, the GPIB ACTIVE mode will have to be re-established.

CAUTION

If the state of the DTR line is changed during any GPIB or RS-232-C data transfer, unpredictable results may occur.

3.6.4 Handshake System

A transfer handshake system is implemented in the Model 552A to help prevent loss of data when data cannot be received as fast as it is sent. The receiver of data must be able to signal to the transmitter that the receiver is not ready to accept more data. This signalling or "handshaking" must be provided for data transfers in both directions.

Two types of handshaking are provided: software and hardware. The software handshake employs XON/XOFF protocol which involves sending these serial control characters to indicate status of the receiving device. Hardware handshaking involves the use of the RTS and CTS lines to indicate receiver status. Depending on the system requirements, either one, both, or neither of these methods may be required.

3.6.4.1 Software Handshake (XON/XOFF)

The XON/XOFF protocol system is a widely-used software handshake system which employs two serial control characters XON ($11) and XOFF ($13), where $ indicates the hexadecimal value of the character.

When the receiver section of either the Model 552A or the controller is unable to accept more data from the transmitter, it sends the XOFF character to the transmitter. Upon receipt of the XOFF character, the transmitter stops sending data.

When the receiver is again ready to accept data, it sends the XON character to the transmitter, which then resumes sending data.

Since the transmitter requires a finite amount of time for receipt and processing of an XOFF character, it is possible that the transmitter will continue to send some characters after XOFF is received. The Model 552A will send no more than three characters following the receipt of XOFF.

When receiving data from the controller, the Model 552A will send XOFF after it receives a command line terminator character. After the command line is processed, the Model 552A will send XON, indicating it is ready for more commands.

NOTE: The controller (transmitter) MUST NOT send more command characters to the Model 552A after the terminator character until it receives XOFF followed by XON. Otherwise, characters may be lost.

To avoid any potential deadlock situations, the Model 552A will not suspend the transmission of XON or XOFF to the controller under any conditions, including a pending XOFF holdoff or a RTS holdoff (see below) by the controller.

The power on default condition of the instrument disables the XON/XOFF protocol. The XON/XOFF protocol may be enabled or disabled under remote control using the 'H' command. (See table 3-9.)

3.6.4.2 Hardware Handshaking

Hardware handshaking features are provided via the two lines RTS and CTS. Note that hardware handshaking is disabled by default at power on, but may be enabled or disabled under remote control using the 'H' command.

Transmitted Data (from the Model 552A)

The RTS line, an input line to the Model 552A, is used by the transmitter section in the 552A as follows:

RTS	Effect
High	552A Transmission Resumes
Low	552A Transmission Halted

By driving the RTS line appropriately, the controller can halt transmitted data from the Model 552A as required. After the Model 552A receives the high-to-low transition of the RTS line, a maximum of three characters may be transmitted before the 552A responds to the halt condition.

Received Data (into the Model 552A)

The CTS line, which is an output from the Model 552A, reflects the status of the receiving cicuitry of the instrument as follows:

CTS	Effect
High	552A Ready to Receive
Low	552A Not Ready to Receive

When receiving data from the controller, the Model 552A will send CTS low after it receives a command line terminator character. After the command line is processed, the Model 552A will send CTS high, indicating it is ready for more commands. The controller (transmitter) MUST NOT send more commands after the terminator charac-

ter until it sees CTS go low and then back high. Otherwise, characters may be lost.

3.6.4.3 No Handshake

It is possible to operate the instrument without handshaking provided. In general, this will involve a slower update rate than that provided by handshaking, but in many applications this is of little consequence.

Transmitted Data (from the Model 552A)

The Model 552A will send data to the controller with no waiting. Therefore, the controller must always be ready to receive data. Of course, with lower baud rates the maximum data rate (characters per second) is reduced. This may allow a slow-responding controller to keep up with data when no handshake is possible.

Received Data (into the Model 552A)

The controller may send data at any of the available baud rates up to the end of a command string. After the command string terminator is sent, no further characters may be sent until after a one second wait for command processing. If the command string contains more than one 'I' command (not usually appropriate), allow an extra second for each 'I'. Following this delay, the Model 552A will be ready to receive the next command string.

3.6.5 Characters

There are five types of characters that can be sent over the RS-232-C serial bus.

Alphabetic Characters: The characters A, C, D, F, H, I, L, M, O, S, and T select filter or control parameter commands; upper and lower case are treated identically. Any other alphabetic characters are ignored except 'E' (see below).

Number Characters: The numbers '0' through '9', 'E' (exponent), '-' (negative), '+' (positive), and the decimal point determine the parameter value or control code.

Interface Control Characters: The characters '!', '$', '?', XON, and XOFF are reserved for special functions.

Terminator Characters: The CR (carriage return) or LF (line feed) characters terminate the end of a character string. Either one or both of these may be present at

the end of incoming strings. When transmitting, the Model 552A always sends both (CR + LF) as a terminator.

Non-programming Characters: Any character not described above is ignored and may be interspersed freely after any programming character.

3.6.6 Types of Commands

There are two types of commands: filter parameter commands and control parameter commands.

Filter parameters deal exclusively with the values of the settings for the filter or gain stages, such as cutoff frequency and input sensitivity. All of these commands are buffered in a scratchpad memory area as they are received, and are not directed to the operational sections of the instrument until the execute (I) command is received.

Control parameters deal with the programming mode and function of the interface but do not directly affect filter settings such as cutoff frequency. These commands are not buffered in a scratchpad memory and do not need an execute (I) command. Their effect is immediate as soon as they are received and processed.

3.6.7 The Execute Command (I)

None of the filter parameters in the scratchpad is executed until the execute command (I) is received. The contents of the scratchpad memory are then transfered to the operational control registers.

An execute (I) may be sent as the last character in the parameter string if the new parameter is to be executed immediately.

It is also possible to send multiple commands in the same string. For example, to send cutoff frequency and input sensitivity in the same string, send the parameter string: 'F10E3S-10I'. In this case, the cutoff frequency of 10 kHz and input sensitivity of -10 dBV are executed immediately and simultaneously.

3.6.8 Error Checking

Upon receipt, each parameter value is rounded to the nearest integer value and then tested to determine if it is a legal value for that parameter.

3.6.8.1 Class 1 Errors - Out of Range

Class 1 errors are errors caused by programming values

outside the valid limits of the selected parameter. For example, programming a cutoff frequency of 100,000 KHz will cause a Class 1 error for frequency (since 50 KHz is the largest valid setting).

When this occurs, the instrument disregards this new value and retains the value previously programmed in scratchpad memory. The error is recorded in the error string and may be examined on request (Talk Mode T0 in table 3-9).

Table 3.7 Class 1 Error Guidelines

Parameter	Must (After Rounding) Be
Frequency (F)	10 to 50000
Input Sensitivity (S)	-60 to +20
Output Gain (O)	0 to 10
Channel Select (C)	1 to 3
Overload Enable (V)	0 to 1
Talk Mode (XT)	0 to 5
Local Mode (L)	0 to 1
Handshake (H)	0 to 3

3.6.8.2 Class 2 Errors - Conflict Between Parameters

Class 2 errors are parameter conflicts or inconsistencies. As the command string is processed, any command which conflicts with another parameter in the scratchpad will cause a class 2 error.

The only class 2 error for this instrument occurs when DC coupling is selected for full scale input sensitivities from -40 to -60 dBV. If this conflict exists, it is resolved by forcing AC coupling into the scratchpad. The error is recorded in the error list.

3.6.8.3 Class 3 Errors - Parameter Needs Adjustment

After integer truncation and testing for Class 1 errors, the parameters are adjusted, if necessary, to the nearest exact value which the instrument can execute.

In the case of input sensitivity, the adjustment is made from the truncated integer value to the next exact 5 dB step value of lower sensitivity (towards a more positive value). In no case is input sensitivity adjusted to a more sensitive setting (more negative value). For example, programmed values of S-31 and S-34 would be adjusted to S-30, (-30 dBV FS). This avoids overload problems for computed gain values.

The output gain is adjusted from its truncated integer value to the closer value of 0 dB or 10 dB.

Since all other parameters are selected in integer steps and have already been truncated, reduced to two-digit resolution (frequency values), and tested for correct range, no adjustments are required. Hence, only input sensitivity and output gain can generate class 3 errors.

Whenever an adjustment is necessary, a class 3 error is reported in the error string buffer. The scratchpad memory is loaded with the adjusted value.

3.6.9 Programming Parameters

Filter and control parameter commands require an alphabetic letter character usually followed by a number value.

Only one decimal point and one 'E' (exponent) are allowed per number, all others are ignored. Only two exponent digits are allowed. Any number of non-programming characters may be interspersed with the numeric field as they have no effect.

Data entry can be fixed point, floating point, exponential notation or scientific notation. Any sequence which gives the new value is acceptable.

For example, all of the following sequences cause the cutoff frequency 100 Hz to be programmed:

Program String	Remarks
F 100	Blank spaces are ignored
F0100	Leading zeroes are ignored
F1E2	$1*10^2 = 100$
F.01E4	$.01*10^4 = 100$
F.01E304	Only last two exponent digits accepted
F1000E-1	$1000*10^{-1} = 100$
F1E-2-	Two minus signs cancel
F1E.2	Decimal point in exponent ignored

Since the numeric input format is so general, the instrument must be told when the last numeric value has been entered so it can evaluate the number. This is done by programming either an alphabetic character or a terminator. When this is done, the new value is rounded and tested to see if it is within range. If so, it is either executed (control parameters) or entered into the scratchpad memory (filter parameters). If it is not within range an error string is generated and the previous value is retained.

3.6.10 Talk Mode

The Model 552A is capable of sending several different messages back to the controller reflecting parameters and status of the instrument. The selection of which message is to be sent is accomplished with the Talk Mode command, Tn, where 'n' is a number between 0 and 6. The description of each command mode is given in Table 3-9 below.

In order to elicit a talk message from the instrument, the controlller must send the interface control character '?'.

When requesting a talk message in talk modes T0, T1 and T6 (all error reporting messages), the errors are cleared after the message is sent. In the other talk modes, the same message may be read any number of times.

3.6.11 Interrupts

The instrument is capable of alerting the controller of an error condition by using the interrupt system. The interrupt sequence consists of sending an escape character (hexadecimal 1B) followed by a CR + LF on the TxD line.

Several types of errors are detected in the instrument. The user can specify which errors are to cause an interrupt. Each error condition is enabled by sending the appropriate error weight using the interrupt mask command. The format for this command is the letter 'M' followed by a decimal number representing the sum of the weights in the following chart.

Weight	Description
128	RS-232-C UART Error
64	(not used)
32	Buffer Overflow
16	Overload Channel 2
8	Overload Channel 1
4	Class 3 Error
2	Class 2 Error
1	Class 1 Error

If any of the above errors is enabled by including its corresponding weight in the interrupt mask, then when that error condition occurs, an interrupt is generated.

For example, if the user required an interrupt for a buffer overflow, an overload on channel 2 or a class 1 programming error, the interrupt mask number (sum of

weights) would be decimal 49 (32 + 16 + 1). The program string would be: 'M49'.

To disable all interrupt error sources, send the string: 'M0'. When the UART error bit is set, either an overrun, framing, or parity error will cause an interrupt.

When an enabled error occurs, the interrupt sequence (ESC + CR + LF) is sent, and the bit in the serial poll byte corresponding to the error is set to one. The bit will remain set until the serial poll byte is read using talk mode T1 (see section 3.6.10).

As errors are detected, the corresponding bits in the serial poll byte are set. The serial poll byte thus represents the accumulated error history since the last time the byte was read and cleared. Note that all errors are recorded in the serial poll byte, not just those enabled with the 'M' command. However, only those errors which are enabled will cause an interrupt.

If the user wishes to know the error history, the serial poll byte may be read at any time using talk mode T1.

NOTE

Programming changes may cause momentary switching transients leading to a false overload indication (interrupt weight 8 or 16). If a transient causes an overload, the error bit in the serial poll byte will be cleared when read by the controller. If the overload is sustained, after the serial poll byte is read and the error bit cleared, the bit will be again set. In this case, however, a second interrupt will not be generated until after the next 'I' command is sent. This avoids a "race" condition where the controller is constantly servicing interrupts.

3.6.12 Programming Reference Guide

A summary of all programming commands follows in three tables. The first shows the special RS-232-C interface control characters. The second shows the control parameters and the third shows the filter parameters. These last two tables are essentially identical to the GPIB commands in tables 3-5 and 3-6.

Table 3-8. RS-232-C Interface Control Characters

Charcter	ACSII (hex)	Function
!	21	Causes the instrument to enter the REMOTE mode, and send DSR line high. Receipt of '!' is equivalent to a low-to-high transition on the DTR line. Return to LOCAL mode can be accomplished by sending a '$' character or a high-to-low transition of the DTR line.
$	24	Causes the instrument to enter the LOCAL mode, and send DSR line low. All subsequent RS-232-C interface signals will be ignored except '!' or a low-to-high transition of the DTR line.
?	3F	Causes the instrument to send the talk message as designated by the talk mode. See section 3.6.10.
XOFF	13	When XON/XOFF protocol is enabled, receipt of XOFF causes the instrument to stop transmitting data. When XON/XOFF protocol is disabled, XOFF is ignored.
XON	11	When XON/XOFF protocol is enabled, receipt of XON cancels the XOFF condition and allows tranmitting of data to resume.

Table 3-9. RS-232-C Control Parameter Programming

Function	ASCII Character	Description
Channel Select	C	The character 'C' followed by a number determines which channel(s) will be affected by subsequent programming parameters according to the folowing table: Code — Function C1 — Channel 1 Only C2 — Channel 2 Only C3 — Both Channel 1 and 2
Execute	I	The character 'I' is causes the sensitivity and coupling parameters in the scratchpad to be checked for conflicts. If no error is found, the rounded scratchpad contents are transferred to the active parameter table and executed. An execute (I) may be sent as the last character in the parameter string if the new parameter is to be executed immediately.
Interrupt Mask	M	The character 'M' followed by number determines which status bits are enabled to cause an interrupt. The number is the ASCII decimal value of the 8-bit mask byte described below: Weight — Description 128 — 1 = RS-232-C UART Error 64 — (not used) 32 — 1 = Buffer Overflow 16 — 1 = Overload Channel 2 8 — 1 = Overload Channel 1 4 — 1 = Class 3 Error 2 — 1 = Class 2 Error 1 — 1 = Class 1 Error If any mask byte bit is set to '1', then when the corresponding condition occurs, an interrupt is generated. If more than one condition is required, then the mask byte should contain '1's for each condition. To disable all interrupts, send the string: 'M0'.

Talk Mode	T	The character 'T' followed by a number code (0 through 6) determines the kind of message the Model 552A will send when requested to do so. All messages are sent in ACSII format with numbers in decimal form. Following each message is a CR + LF. Additionally, for GPIB, the EOI line is asserted. Code Function **T0 Program Error List** A typical error string is: E1F 2DS The error string has the following characteristics: a. All error strings begin with E. b. Most recent error is at the end of the string. c. Errors are separated by a space. d. Class 1 error: The number '1' followed by the program character that caused the error. (Example, 1F) e. Class 2 error: The number '2' followed by 'DS', since DC coupling (D) and Sensitivity (S) are the only two possible conflicting parameters. f. Error strings can be up to 80 characters long. g. After transfer, the error string is cleared. **T1 Serial Poll Byte Response** The serial poll status byte is converted to an ASCII decimal number between '0' and '255'. After the string is sent, the serial poll status byte is cleared to all zeroes and in the GPIB mode, the SRQ line is released. Each bit is latched and even if the error condition is removed, the bit will remain set until cleared by

reading the byte.

The serial poll status byte has the following format:

Weight	Description
128	1 = RS-232-C UART Error
64	1 = GPIB Request for Service
32	1 = Buffer Overflow
16	1 = Overload Channel 2
8	1 = Overload Channel 1
4	1 = Class 3 Error
2	1 = Class 2 Error
1	1 = Class 1 Error

For example, if the number '13' were received (13 = 8 + 4 + 1), a channel 1 overload, a class 3 error, and a class 1 error occured since the byte was last read.

T2 Most Recent Parameter String

The most recently programmed parameter string is sent. All RS-232-C interface control characters are removed from the string.

T3 Entire Active Instrument Setup

All control and operating parameters for both channels are sent. Example: C1 F12000 S-60 O00 A C2 F300 S-00 010 D M008 H2 T3 L1 C1.

The C field precedes the settings for each indicated channel. The F field expresses the cutoff frequency in Hz, no leading zeroes. The S field shows full scale sensitivity in dBV with sign and two digits. Output gain in dB is indicated by O followed by 00 or 10. AC or DC input coupling is shown by the single letter A or D.

The interrupt mask is a three-digit decimal number following the letter M. Handshake Mode, Talk Mode, and Local (Front Panel) Control Mode are all indicated by the single letters H, T and L, respectively, each followed by a single digit.

The final C channel specification shows which channel(s) is selected for subsequent programming.

Note: This string fully represents the instrument configuation. It can be stored and later sent exactly as is into the instrument to restore this configuration.

T4 Entire Scratchpad Setup

All filter parameter scratchpad values that will be exectuted with the next execute (I) command are sent. Same format as T3 except only the C, F, S, O, A and D parameters are included.

T5 Identification

Instrument identification and software revision. Example: WAVETEK MODEL 552A REV C.

T6 RS-232-C UART Status

The UART (Universal Asynchronous Receiver/Transmitter) for the RS-232-C port can report its error status with an ASCII decimal number between '0' and '7' according to the table below:

Weight	Description
4	1 = Framing Error
2	1 = Parity Error
1	1 = Overrun Error

For example, a response of the number '5' would indicate an overrun error and a parity error. Once the status is read, it is cleared to '0'.

Exponent E

Designates that the numbers immediately preceding 'E' to be raised by the 10th power of the following number, and optional '+' or '-' sign. Example: F300E-1 = $300*10^{-1}$ = 30 Hz.

Local Control L

The character 'L' followed by a number allows the front panel keys to be enabled or disabled during remote control operation according to the following table:

Code	Function
L0	Front Panel Disabled
L1	Front Panel Enabled

The power up default condition is L0.

Handshake H

The character 'H' followed by a number allows alteration of the software and hardware handshake protocols described in section 3.6.4 as follows:

Code	RTS/CTS (Hardware)	XON/XOFF (Software)
H0	Off	Off
H1	On	Off
H2	Off	On
H3	On	On

Note: The power up default condition is H0. Disabling XON/XOFF protocol will clear an existing XOFF condition.

Table 3-10. RS-232-C Filter Parameter Programming

Function	ASCII Character	Description
Input Coupling	A	The character 'A' selects AC input coupling for the selected channel(s). No number value is required following the 'A'.
	D	The character 'D' selects DC input coupling for the selected channel(s). No number value is required following the 'D'.
Cutoff Frequency	F	The character 'F' followed by a number value programs the filter cutoff frequency in Hz for the selected channel(s). Valid values are 10 Hz to 50,000 Hz.
Output Gain	O	The character 'O' followed by a number value determines the post-filter output gain in dB for the selected channel(s). Valid values are either 0 dB or 10 dB.
Input Sensitivity	S	The character 'S' followed by a number value determines the full scale input sensitivity of the selected channel(s) expressed in dBV, where 0 dBV equals 1 Vrms. Valid values are -60 dBV to +20 dBV, in increments of 5 dB.

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